

Coastal defence

Soft or Hard

Economic development or ecosystem management

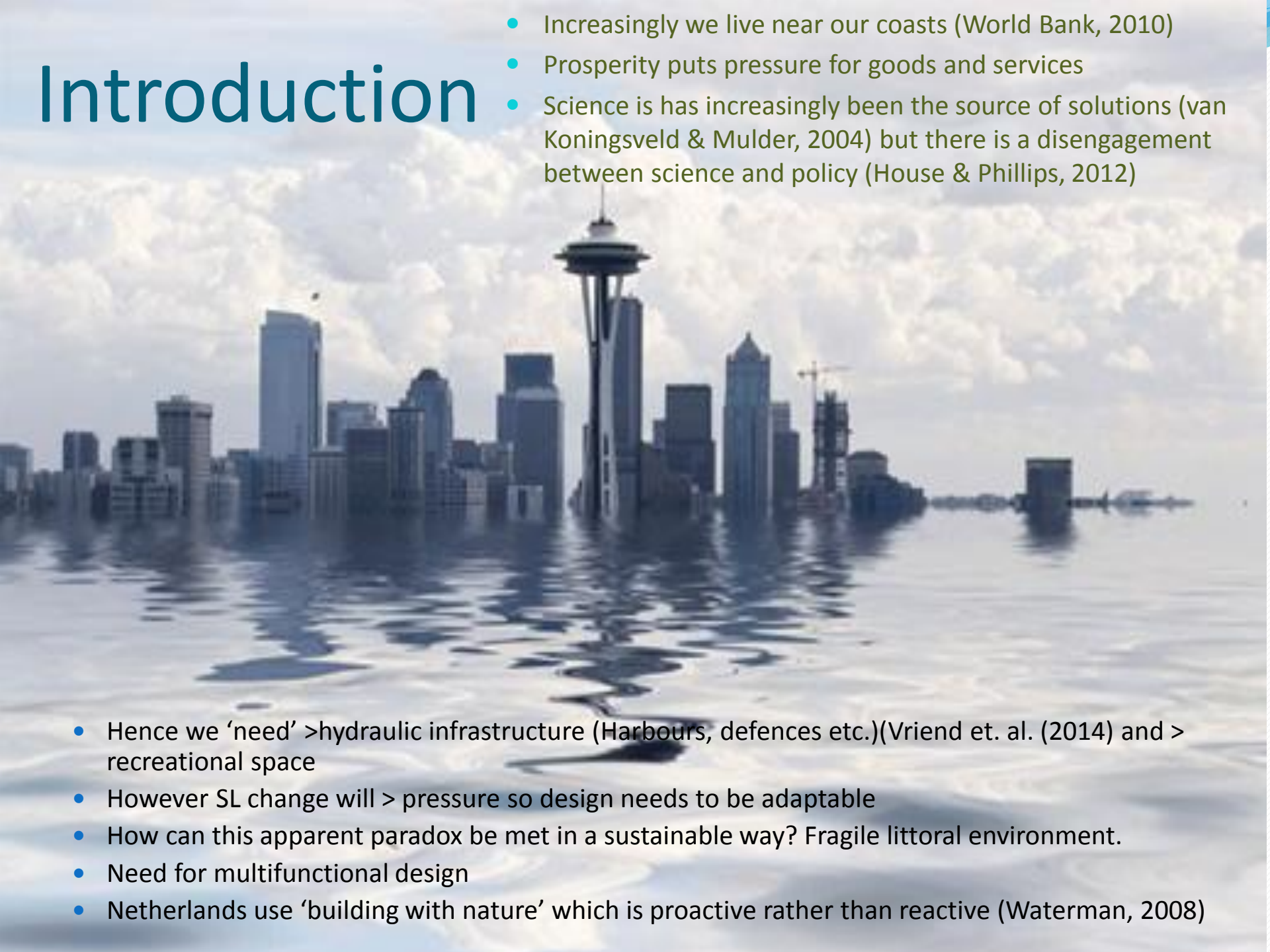
Can we have both?



Introduction

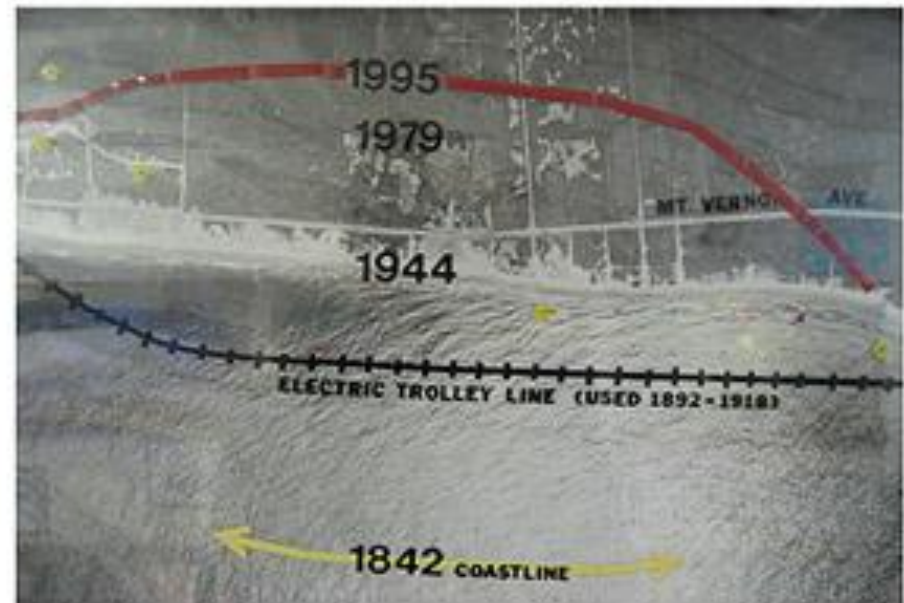
- Increasingly we live near our coasts (World Bank, 2010)
- Prosperity puts pressure for goods and services
- Science is has increasingly been the source of solutions (van Koningsveld & Mulder, 2004) but there is a disengagement between science and policy (House & Phillips, 2012)

- Hence we 'need' >hydraulic infrastructure (Harbours, defences etc.)(Vriend et. al. (2014) and > recreational space
- However SL change will > pressure so design needs to be adaptable
- How can this apparent paradox be met in a sustainable way? Fragile littoral environment.
- Need for multifunctional design
- Netherlands use 'building with nature' which is proactive rather than reactive (Waterman, 2008)



A Diachronic example

- In 1801, Postmaster Ellis Hughes of Cape May, New Jersey, placed the following advertisement in the Philadelphia Aurora:
"The slope of the shore is so regular that persons may wade a great distance. It is the most delightful spot that citizens can go in the hot season."
- This was the first beach advertisement in America and sparked the beginning of the American rush to the shore.
- In the next 75 years, six Presidents vacationed at Cape May. At the time of the Civil War it was certainly the country's most prestigious beach resort. The resort's prestige continued into the 20th century. In 1908, Henry Ford raced his newest model cars on Cape May beaches.
- Today, Cape May is no longer found on anyone's list of great beach resorts. The problem is not that the resort is too old-fashioned, but that no beach remains on the cape due in part to beach management (coastal care.org, 2014)

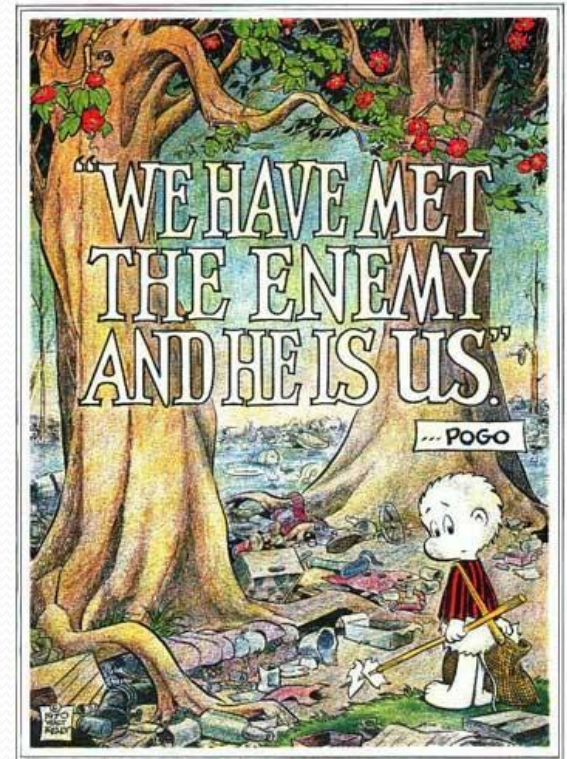


Capemay.com, 2014

Two ends of a spectrum



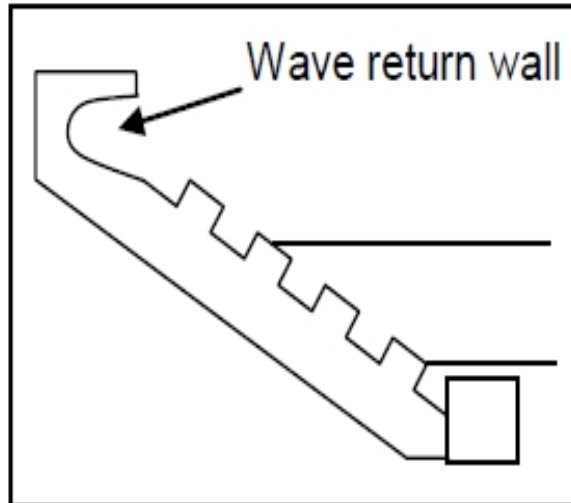
- Hard engineering
 - Controlled disruption of natural processes by using manmade structures: Sea walls (e.g. tetrapods), revetments (e.g. riprap / Rock armour), Groyne, Gabion (can be a seawall, revetment etc), offshore breakwater . . .
- Soft engineering
 - The use of ecological principles and practices to reduce erosion, save money, help stabilisation, and improve safety while enhancing habitats and aesthetics. Often cheaper and sustainable E.g. Vegetation, nourishment, cliff regrading, beach reshaping, managed retreat, coastal realignment . . .
- But what about: **Durability, Cost, Effectiveness**



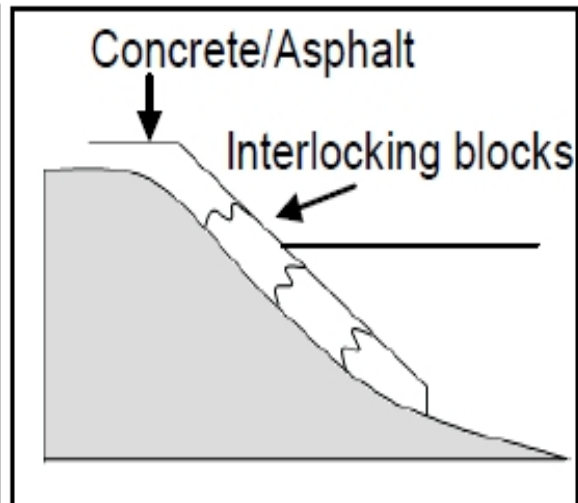
Hard engineering



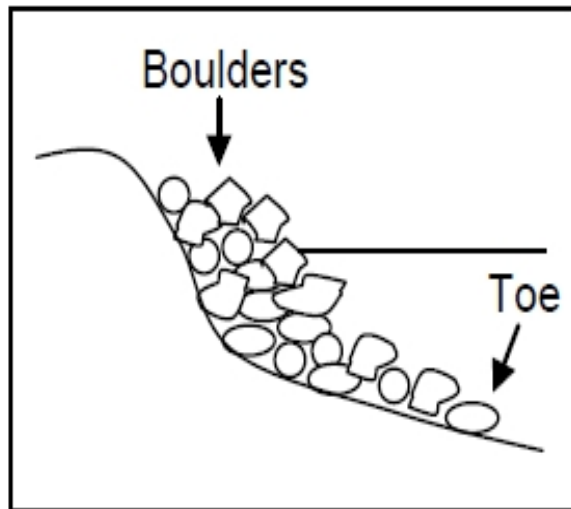
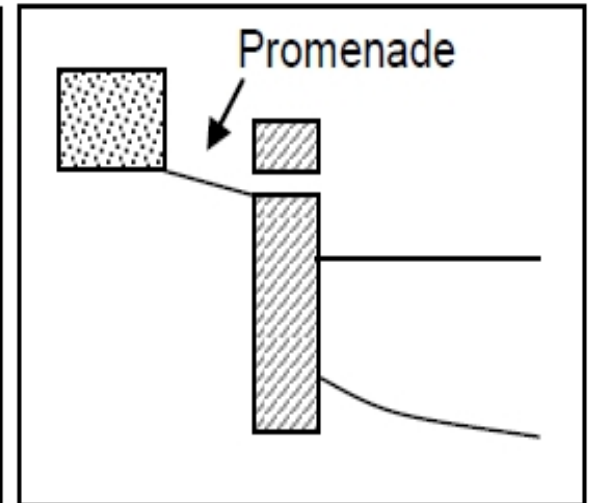
Irregular Face



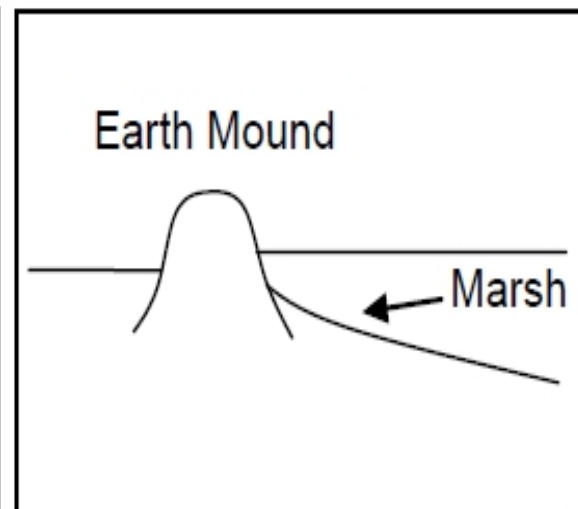
Revetment



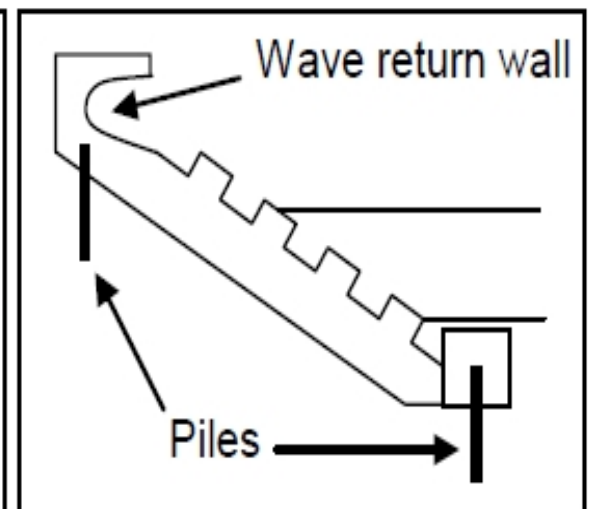
Vertical Wall



Rubble Mound



Embankment



Curved/Stepped

Hard, concrete structures are typically replaced by revetments and embankment-type structures in more sheltered environments

Sea walls



- Provides excellent protection and safety BUT:
- Seawalls reflect wave energy, ultimately removing the beach and steepening the offshore profile. (The length of time required for this damage to occur is one to thirty years.) The steepened offshore profile increases the storm-wave energy striking the shoreline; this in turn increases erosion.
- Seawalls can increase the intensity of longshore currents, hastening removal of the beach
- Seawalls prevent the exchange of sand between dunes and beach. Thus, the beach cannot supply new sand to the dunes on the island, nor flatten as it tends to do during storms.
- Seawalls can concentrate wave and current energy at the ends of the wall, increasing erosion at these points.

(Coastal care.org, 2014)

- Cost and environmental impact

Seawalls have a 'lifecycle'

UNDEVELOPED BEACH

Balanced erosion and replenishment maintain a stable beach

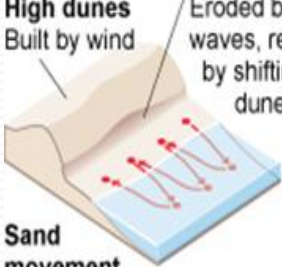
High dunes
Built by wind

Scarped dune

Eroded by storm waves, restored by shifting dunes

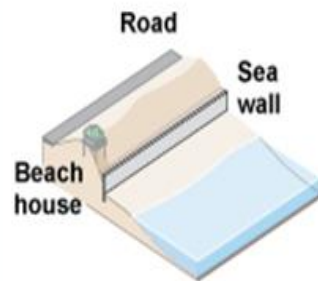
Sand movement

As they retreat, waves drag sand straight out and redeposit it farther down the beach as they break onshore at a slight angle.



NEW SEA WALL

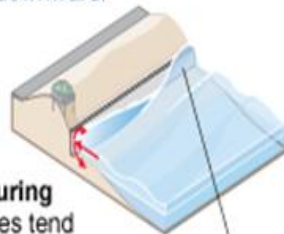
Walls are designed to protect shorefront development from the battering of waves.



WAVE ATTACKS

When high tides and storms drive waves into the wall, the forward force is redirected both upward and downward.

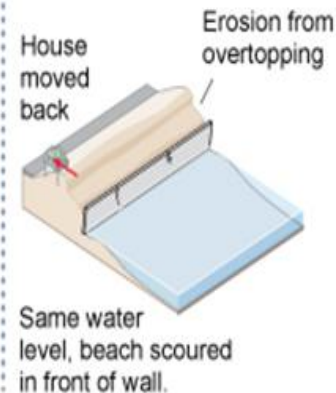
Scouring
Waves tend to dig a trench in front of wall.



Overtopping
Waves breaking over the wall erode sand behind it.

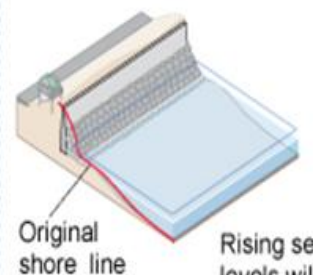
OLDER SEA WALL

Years of overtopping and scouring, along with wear from wave-driven rocks and sand, destabilize the wall.



REINFORCED SEA WALL

The enlarged and rebuilt wall blocks the development from the water. In some cases, the beach will have disappeared.

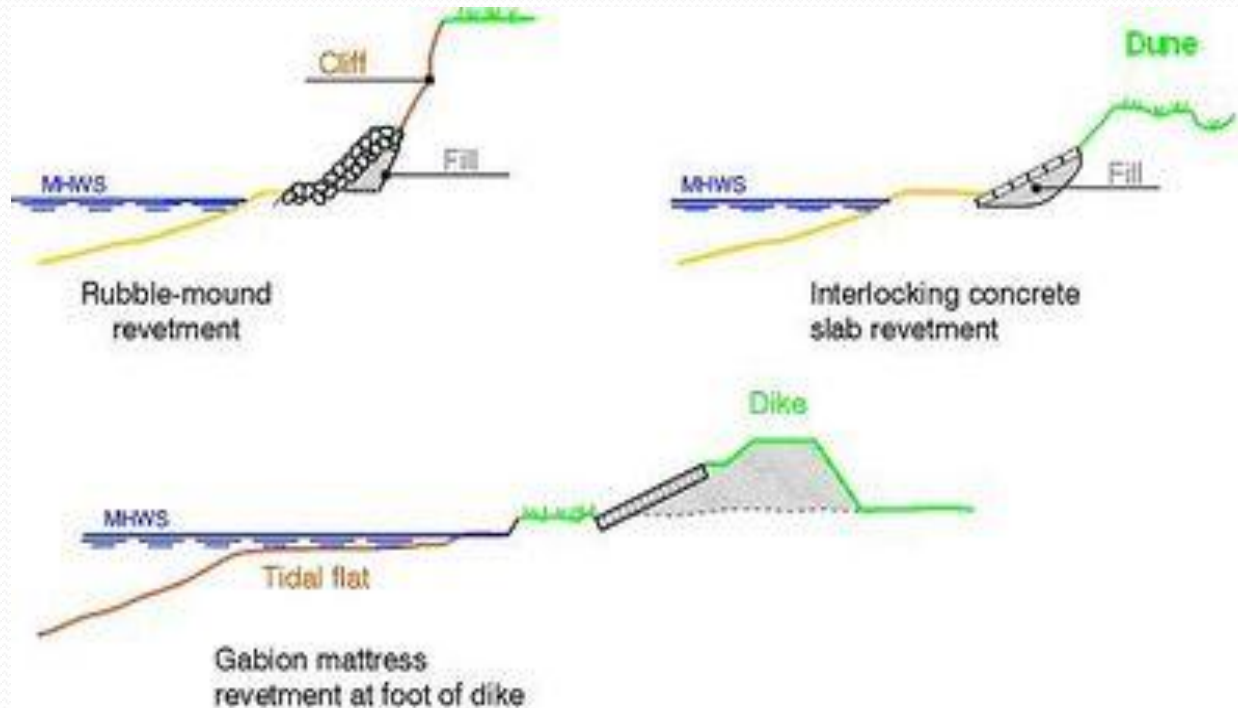


Seawalls: Tetrapods

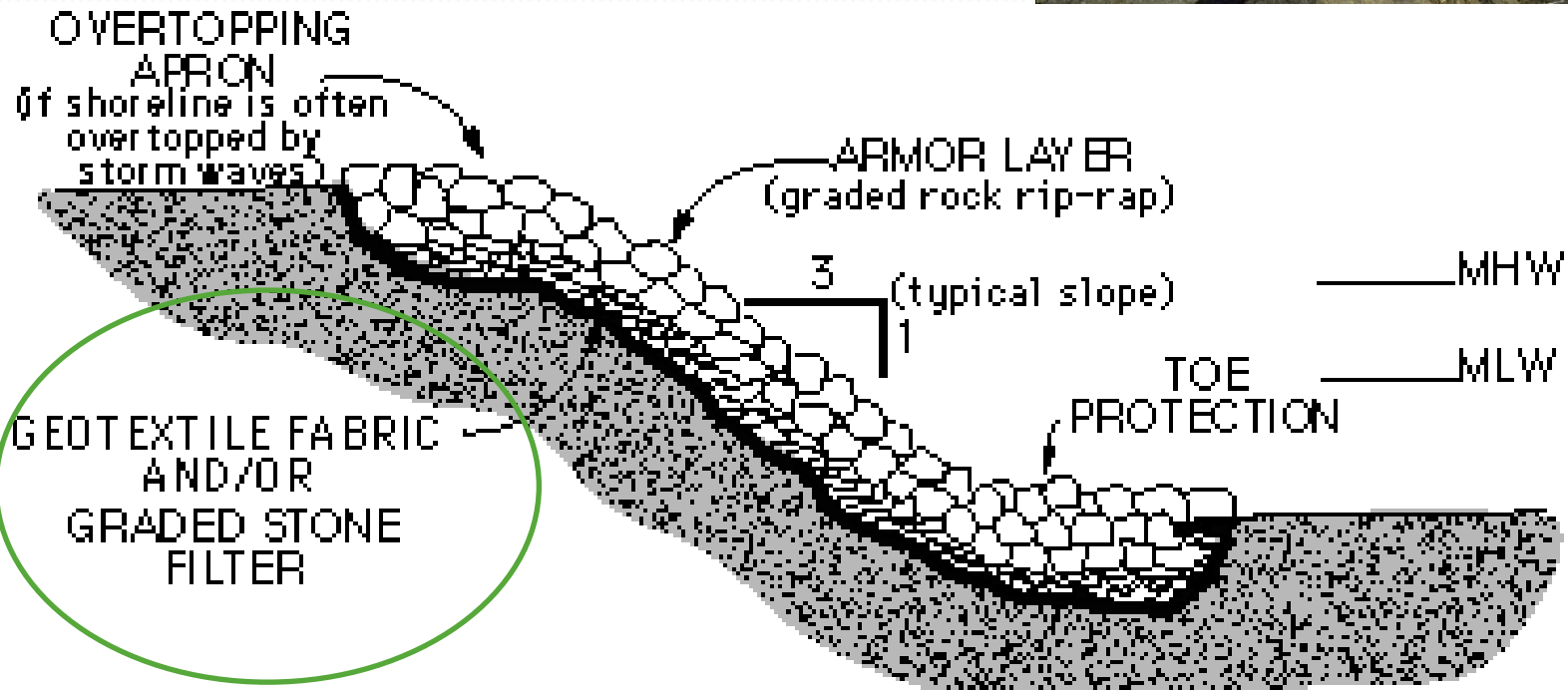


Revetments

- Sloping structures that absorb wave energy and minimise reflection
- Wood, concrete sand filled geotextiles, gabions etc. often used to reinforce seawalls that have lost their beach but unlike seawalls does not protect against flooding (Just erosion).
- Poor for recreation and fishing industries because of the steep slope



Rip rap revetments (Rock armour)

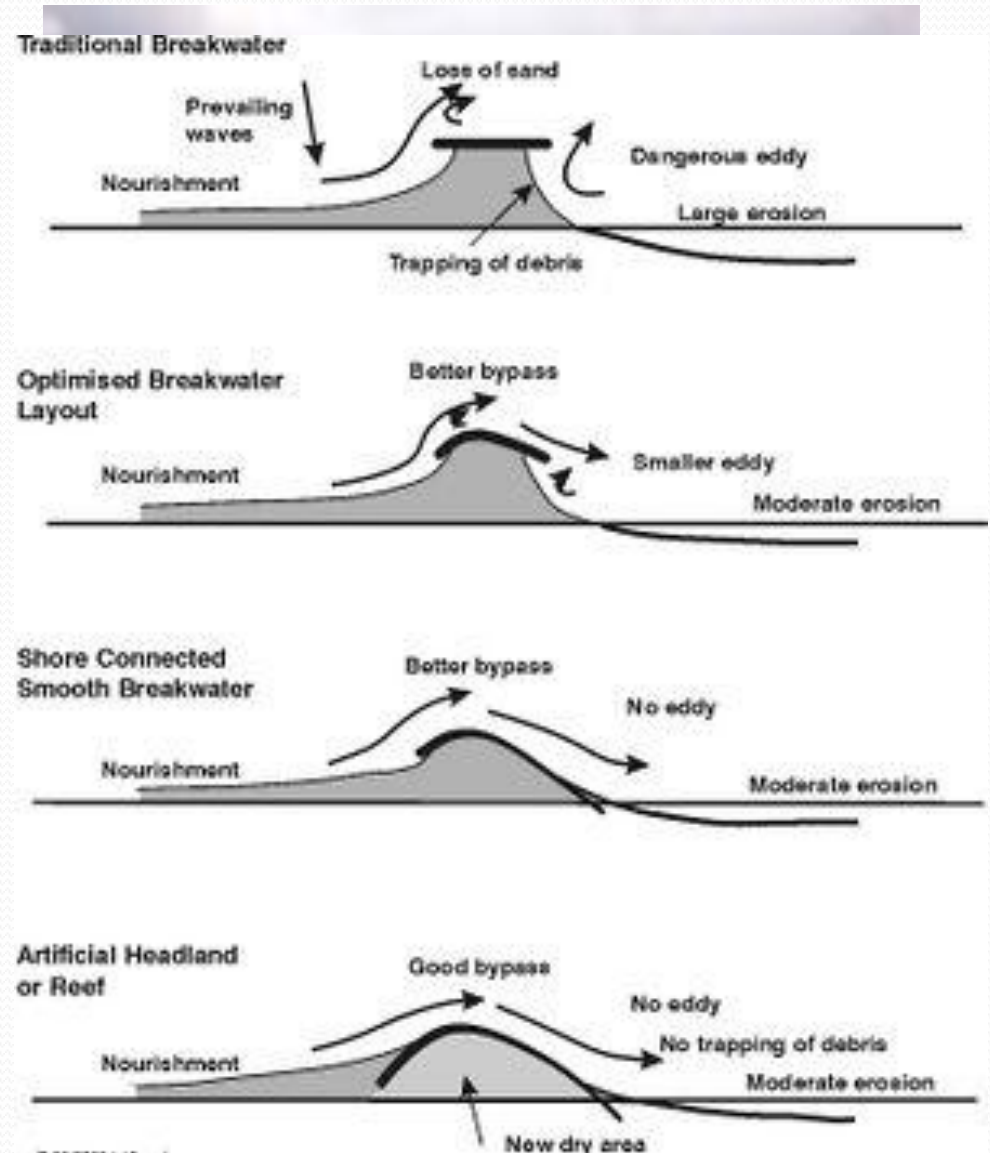


Portugal



Offshore breakwater

- Submerged or non submerged
- Floating or curved or straight.
- How far offshore?
- **Reasons for selecting a submerged/low breakwater**
 - The visual impact of a submerged/low structure is less damaging
 - A submerged or low-crested structure is less expensive
 - The impact on the transport climate and on the deposition is smoother
 - The overtopping water generates good water circulation behind the breakwater
 - Submerged breakwaters are very similar to natural reefs. They attract fish and are therefore popular among fishermen



Cont'd

- **Disadvantages of submerged/low crested breakwater**
 - A submerged structure can be dangerous for small craft navigation
 - The overtopping water initiates local currents, which can be dangerous for swimmers
 - A submerged or low-crested structure provides only partial attenuation of the wave action as well as partial shore protection and coast protection
 - The design is very difficult and challenging because the proper function of a submerged or low-crested structure depends on both water-level and wave conditions as well as on the specific structure.

(Coastal wiki.org, 2014)

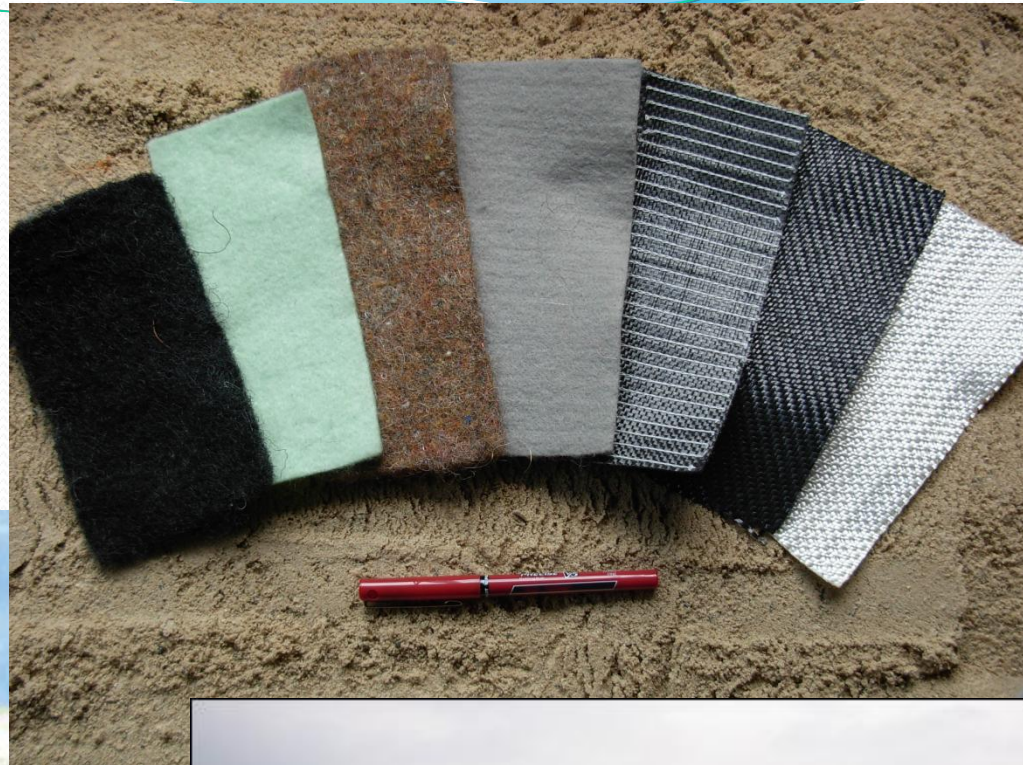
- E.g. Sea Palling, Norfolk

Some materials used in coastal engineering



Geotextiles

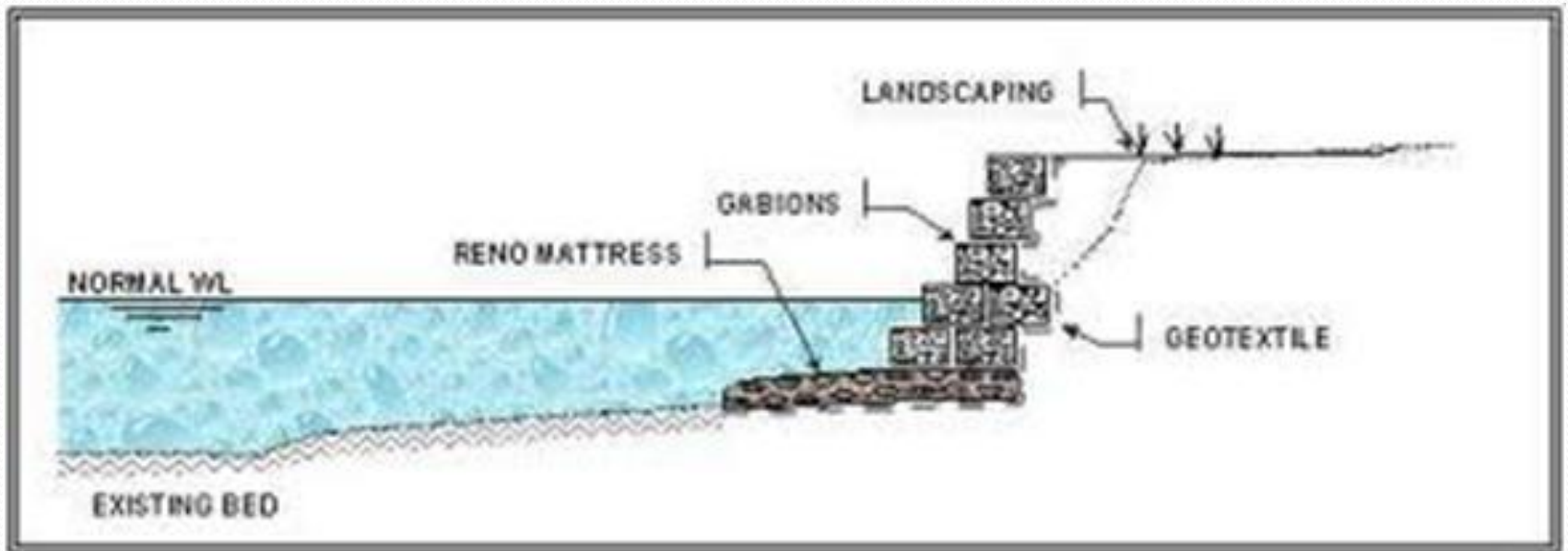
- Permeable fabric to protect since the 1950s. Often behind seawalls



Geotextile Tube Sea Wall at Shankarpur during High Tide, W.B.

Gabions

- Gabions are wire cages usually filled with crushed rocks, and then piled up along the shore to prevent or reduce coastal erosion by weakening wave energy.
- Only short-term protection (about five to ten years). Wire cages need regular maintenance as they are easily corroded by sea water.
- Aesthetics?



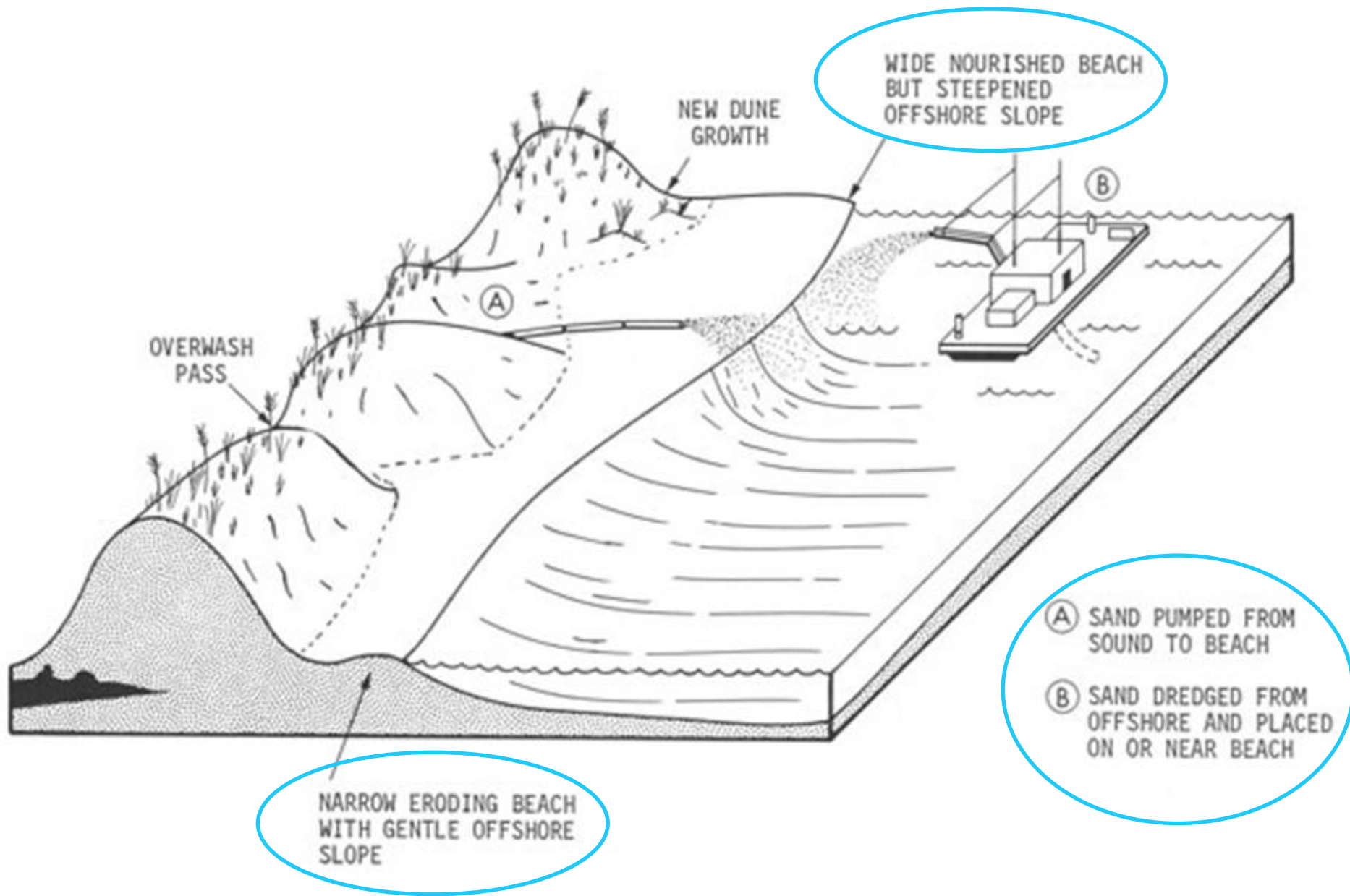
Soft Engineering



Beach nourishment

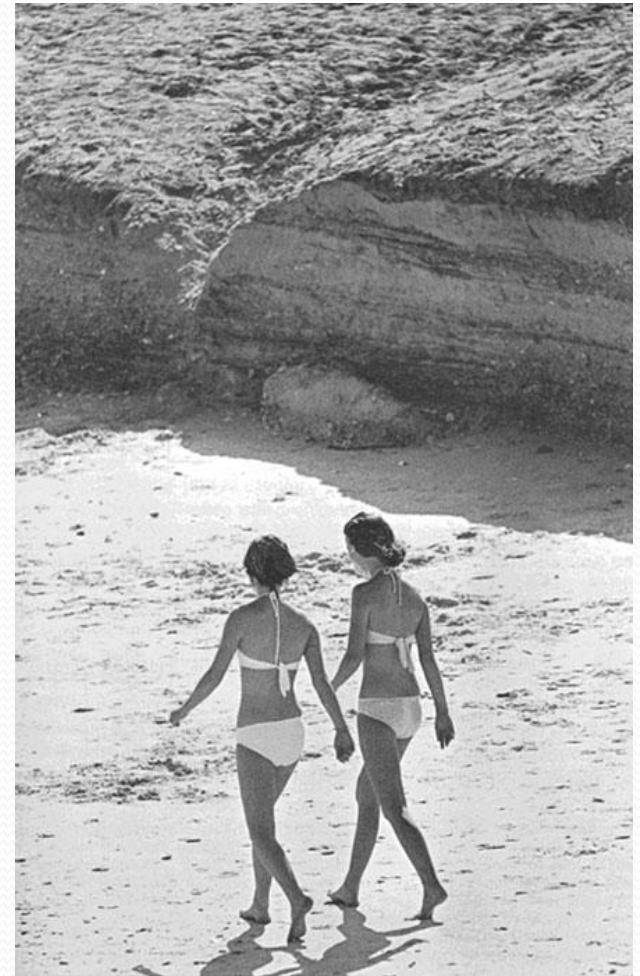
- Beach nourishment Refers to constant replenishment of large quantities of sand to the beach system. Beach is therefore extended seawards, leading to improvement of both beach quality and storm protection. Usually dredged (Various types of dredging) offshore and planted in required area.
- Needs to be carefully considered not to cause problems
 - Short term mortality
 - Burial
 - Reduced light
 - Toxicity
 - Can cause erosion
 - Increased development pressure because of cost and misguided sense of security
 - High proportions of suspension in water column





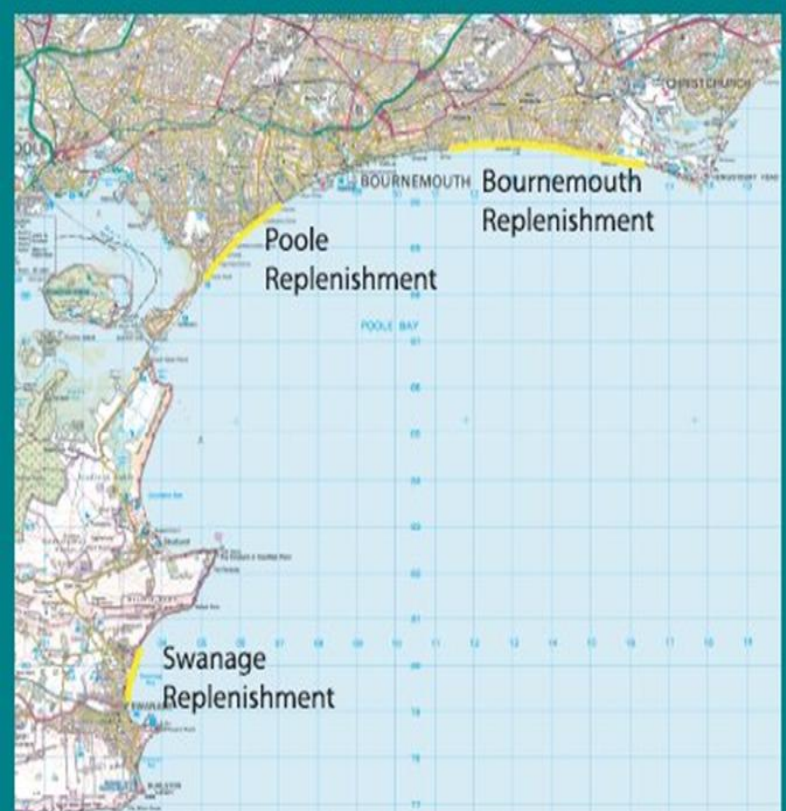
The Wrightsville case

- In 1965 one of North Carolina's most publicised beach replenishment projects was undertaken at Wrightsville Beach. Nearly 3 million cubic yards of sand were pumped onto 14 thousand feet of beach. Parts of the beach were replenished in 1966 and in 1970, but much of that sand was later lost. In the summer of 1976 the City was worried because the beach had become very steep. A bulldozer was used to flatten the beach slope by pushing sand from the artificial dune out onto the beach. By the summer of 1977 the beach was again very steep and a scarp had formed.
- The real problem with this example of beach replenishment, however, comes with cost and sand supply. The cost of the Wrightsville Beach project was over \$1 million in 1966. (Coastal care. Org, 2014)



Wrightsville Beach Scarp

Figure Sand for this beach replenishment is being pumped from the nearshore onto the beach



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Figure Beach replenishment in Miami, Fla. This project restored a declining tourist industry and paid for itself in revenue.

Relocation

- Relocation of Property - E.g. England – “Green Line” policy which discourages any building beyond a given line. Any properties built beyond the given line will not be defended or protected should they be threatened by coastal erosion.
- Opposition by people with considerable investments in coastal areas . This approach will be important in future coastal management due to rising sea level as a result of global warming.

Ecosystem engineering

- Building with Nature (BwN)
- Much of present-day coastal infrastructure offers perspectives not only to protect the coast, but also to create suitable habitats for certain ecosystems. This can be beneficial, as natural ecosystems can contribute significantly to coastal protection and provide other services. Moreover, most ecosystems, as opposed to traditional hard structures, are able to adapt to (relative) sea-level rise
- Coral, mangrove, saltmarshes, seagrass and shellfish
- E.g. Oysters can be used to protect other habitats such as intertidal flats, saltmarshes and submerged aquatic vegetation (van Wesenbeeck *et al.*, 2011).
- Read articles on Moodle
 1. *Firth et al. (2014) Between a rock and a hard place: Environmental and engineering considerations when designing coastal defence structures*
 2. *Ng et al (2014) Maintaining a way of life for São Miguel Island (the Azores archipelago, Portugal): An assessment of coastal processes and protection*

Oyster reef



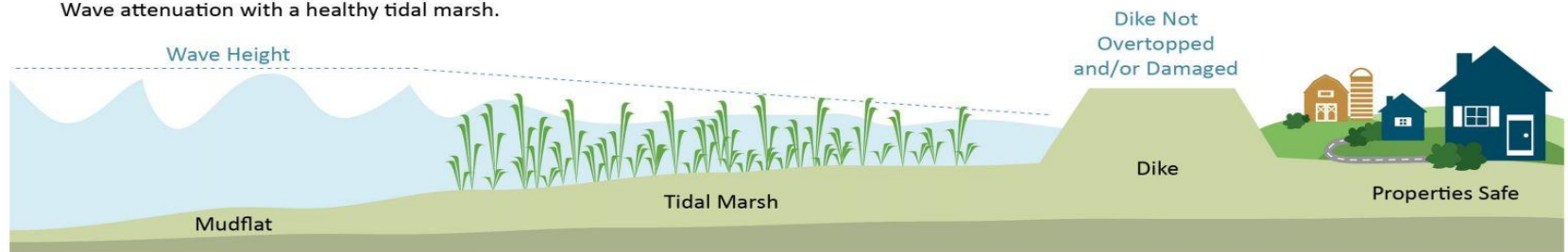
Artificial oyster reef, Eastern Scheldt

Saltmarsh

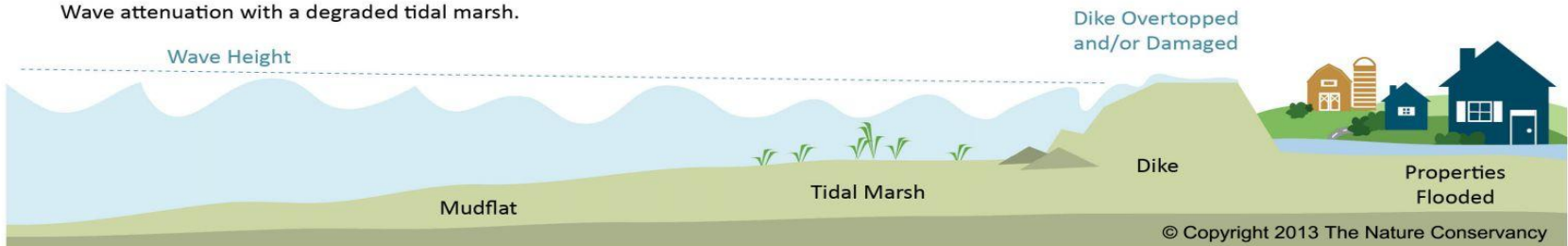
Coastal Defense

Coastal Defense quantifies how natural habitats (oyster reefs, tidal marshes, seagrass ...) protect coastal areas by reducing wave-induced erosion and inundation. It uses standard engineering techniques to help you estimate how and where to restore or conserve critical habitat, and increase the resilience of your coastal community and infrastructure.

Wave attenuation with a healthy tidal marsh.

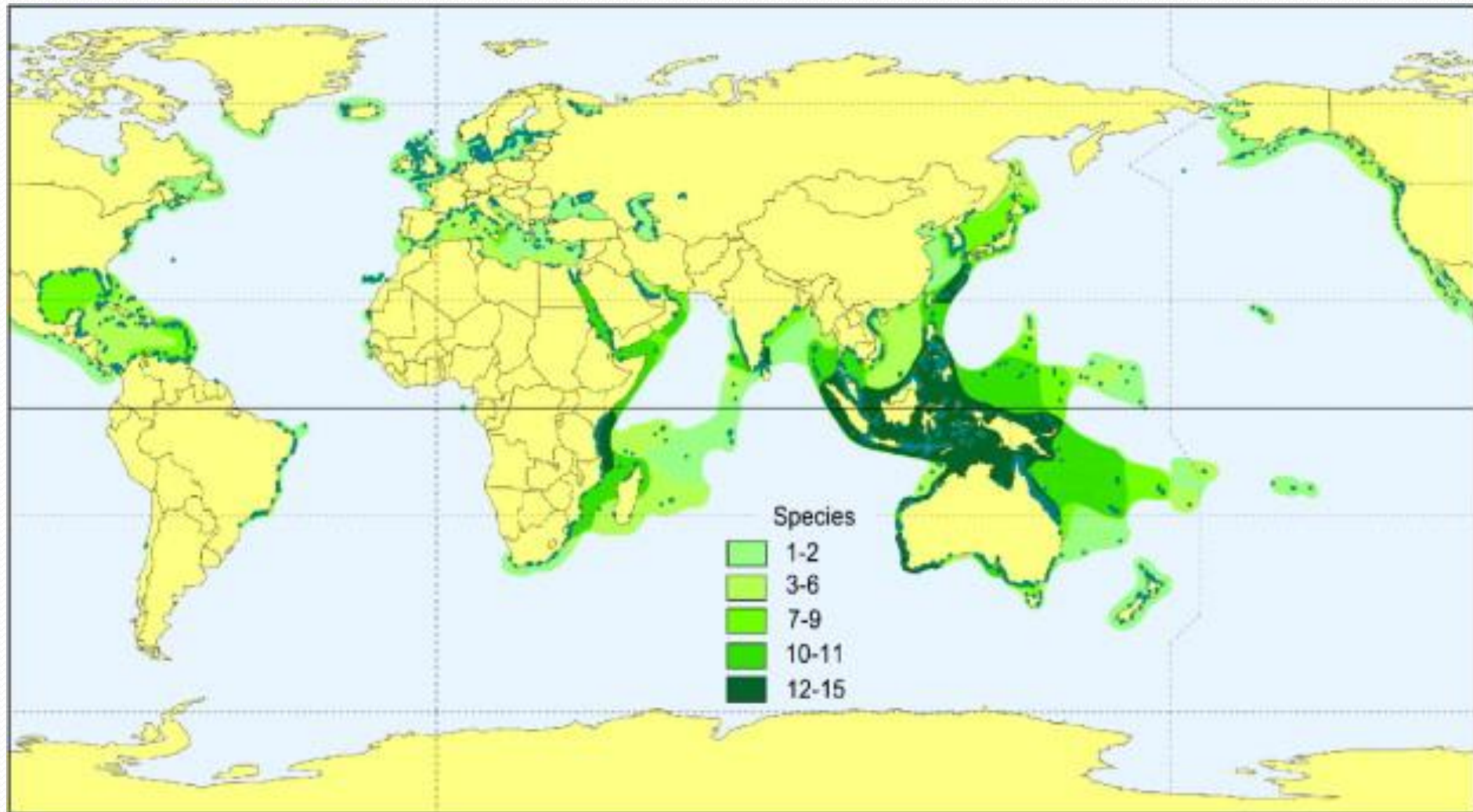


Wave attenuation with a degraded tidal marsh.



© Copyright 2013 The Nature Conservancy

Seagrass e.g. Wadden sea, Netherlands





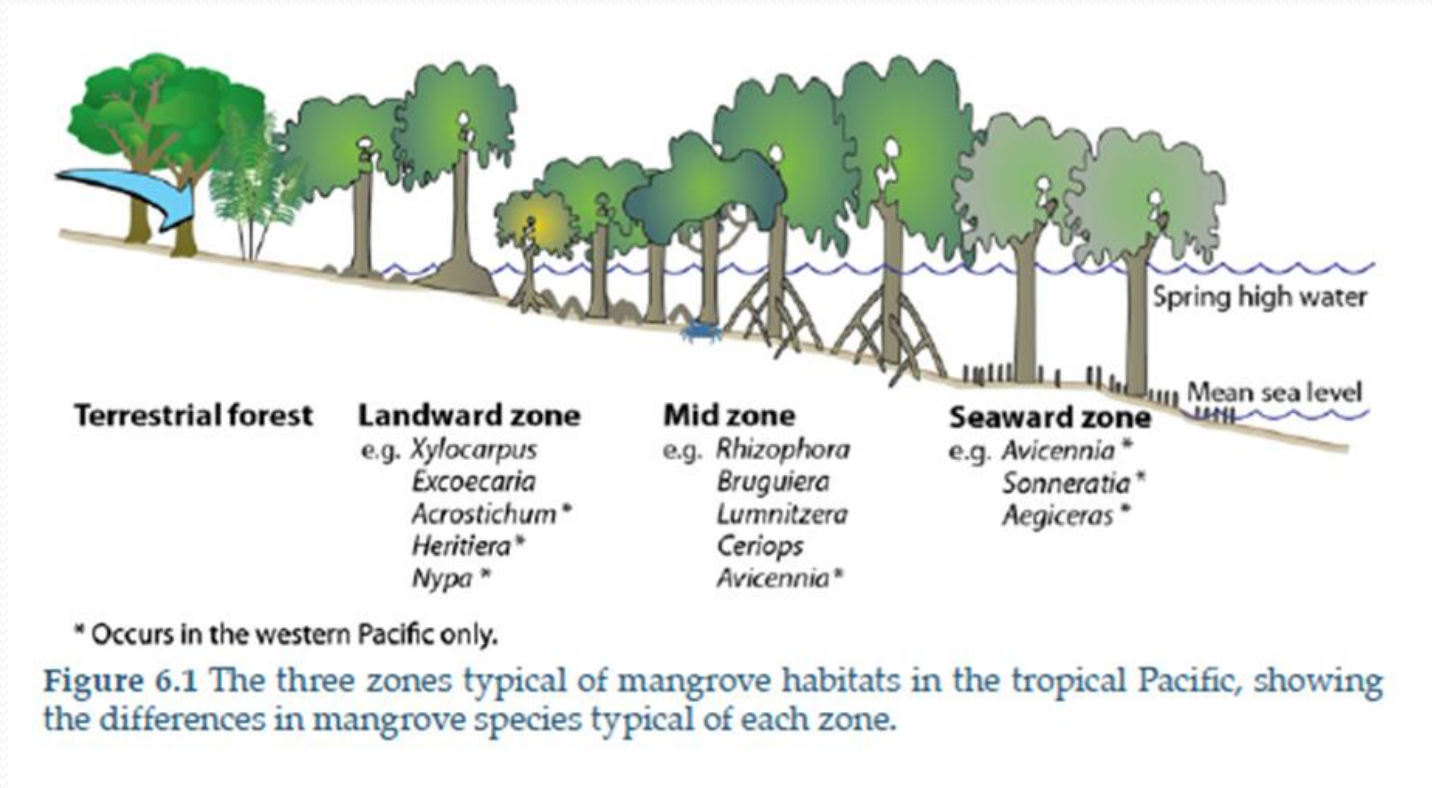
Mangroves

- Mangrove forest consists of trees and shrubs that can tolerate regular flooding by seawater. This tolerance is due to one of the most distinct characteristics of the mangrove trees: aerial roots which are part of the day exposed to the air, and thereby enable them to survive tidal inundation and anoxic (depleted dissolved oxygen) sediments.



Mangrove zonation

- Planting of Mangroves (-) Not all coastal regions can support mangroves, especially in coastal regions with destructive waves. As sediments build up along coast after planting mangroves, depth of coast may become shallower and thus affect port activities – (E.g. Pose a problem for countries like Singapore that depends heavily on maritime trade.)



Conservation

- Thailand and turtle conservation (Naurcrates programme)
- Shrimp farm pressure



MANGROVE FOREST RESTORATION

+ carbon storage and
carbon sequestration

+ support of (globally) threatened
species and fragile ecosystems

+ providing resources
(construction, food, etc.)

+ absorption and immobi-
lization of pollutants

+ ...

+ protection and stabilisation of
coastal zones

+ supporting biodiversity

+ impeding the speed of cyclones
and tsunamis and reducing the
impacts of flooding

+ providing medicines for diarrhoea,
blood pressure, asthma, viral/
bacterial infections, snake bites, etc.

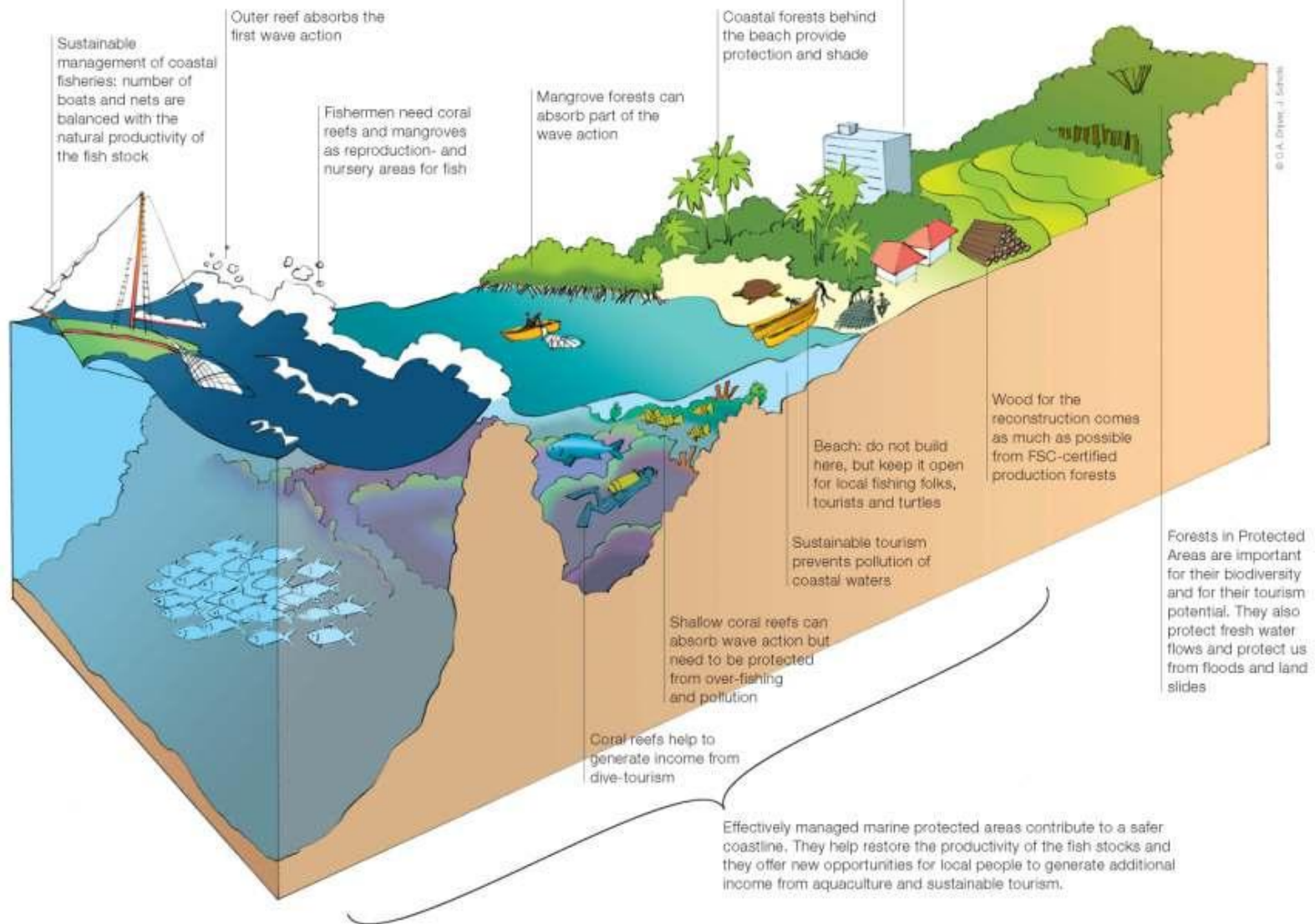
Coral

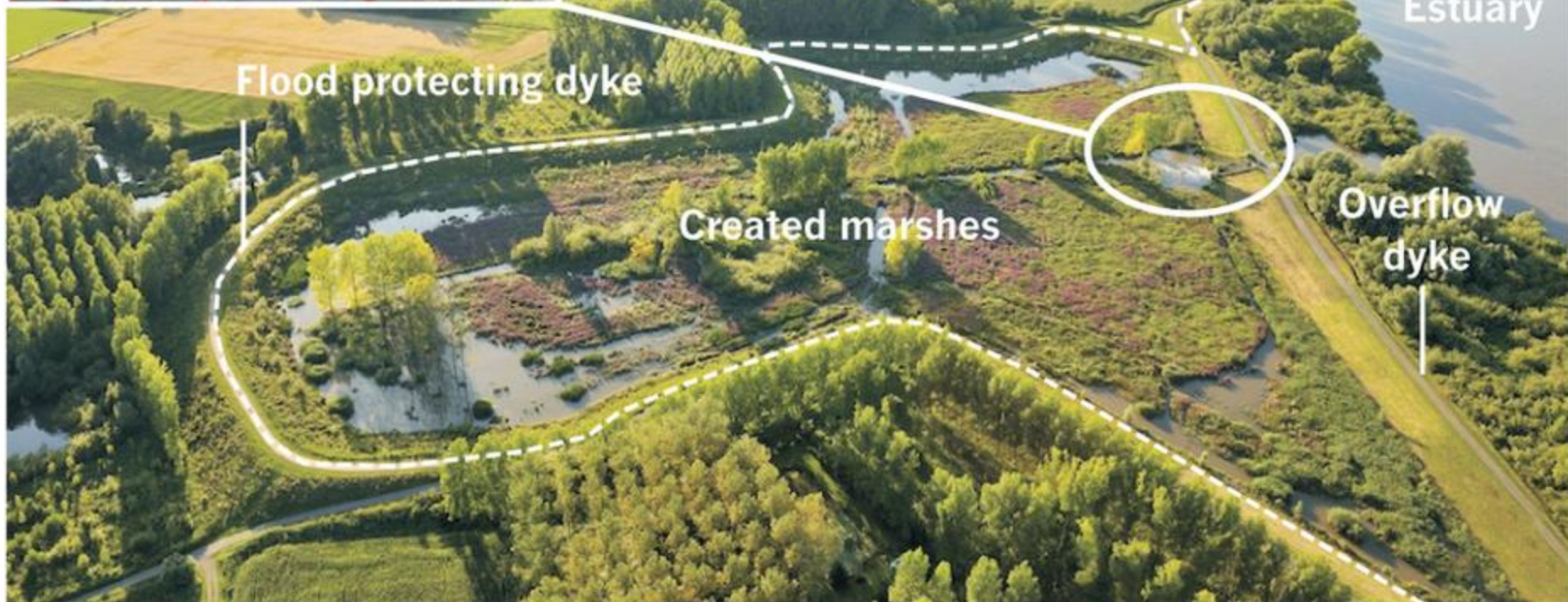


- There is increasing effort to identify ecologically-friendly alternatives to shoreline armouring.
- Most frequently and successfully employed are hybrid approaches that incorporate built structures in combination with ecosystem engineers such as vegetation, or with habitat-enhancing alterations.
- Completely soft-engineering strategies, which often include habitat restoration or rehabilitation, require the incorporation of engineering principles towards the primary functionality of the design.
- The establishment and persistence of coral communities are wholly dependent on a suite of highly-linked variables that in total define the environmental conditions of coral taxa
- E.g. Puerto Caucedo Dominican Republic.(Deltares, 2014)

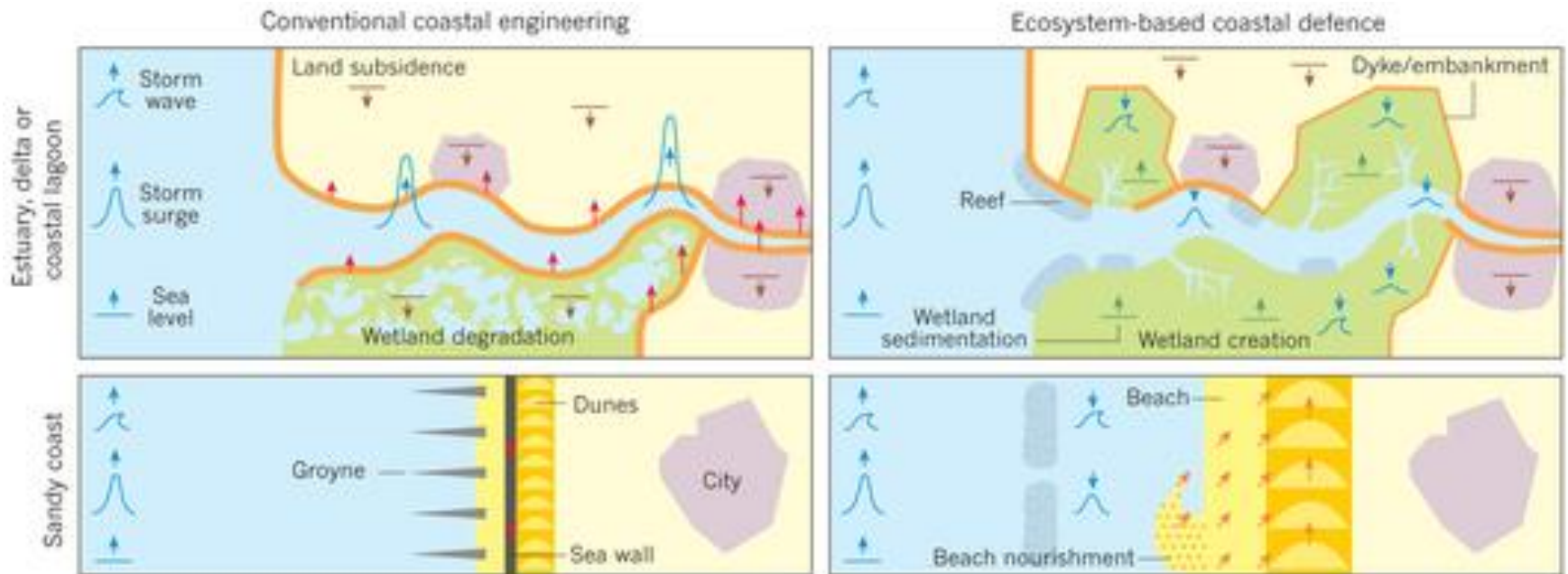
Securing the future after Tsunami

The concept of a well reconstructed coastal zone. Coastal protection as well as the long term security of food and income enhanced when sustainable tourism and -fisheries management are combined with the rehabilitation and management of natural resources





Ecosystem based coastal defence



- **Temmerman et al (2013) Ecosystem-based coastal defence in the face of global change Nature 504**

Other

- Stabilising dunes
- Artificial reefs weaken wave energy. Artificial reefs can be created along coast by placing environmentally friendly and durable materials such as steel or concrete on sea floor. These man-made reefs enhance fishing opportunities and serve as undersea barriers to reduce impact of wave energy e.g. tyres
- Emergency protection: Rock dumping, sand bags, other material e.g. tyres (Mangor, 2004)
- Tidal Lagoons?



Artist's Impression

Managed retreat

- [bbc 6mins Minehead](#)



Prior to Realignment

Coast defences present
Little intertidal habitat



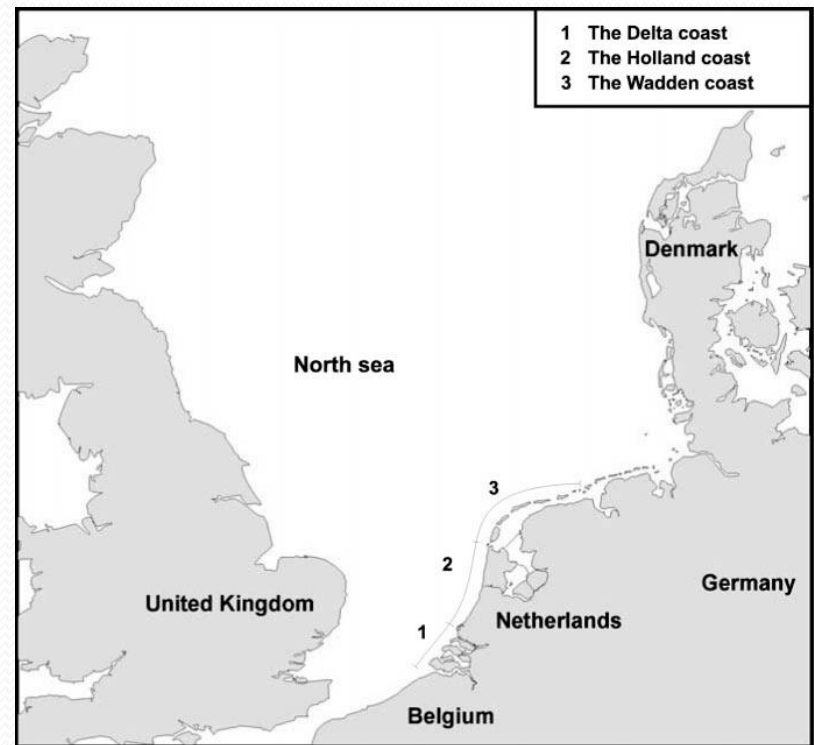
Managed Realignment

Coastal defences breached
Creation of intertidal habitat



Coastal Management Case study: Netherlands

- Coast 350 km
 - Delta coast is dominated by tides
 - Holland: storm dominated sandy beach
 - Waddon is barrier islands
- 50% is prone to erosion
- Since 1953 dominated by protection from flooding and hard engineering
- Erosion due to diminishing river sediments, land subsidence & SL rise (Strive et al, 2011)
- Storm surge barriers
- Then a 'new' approach Dynamic Preservation Policy since 1990 *sustainable preservation* maintain line. (Roelse, 2002)

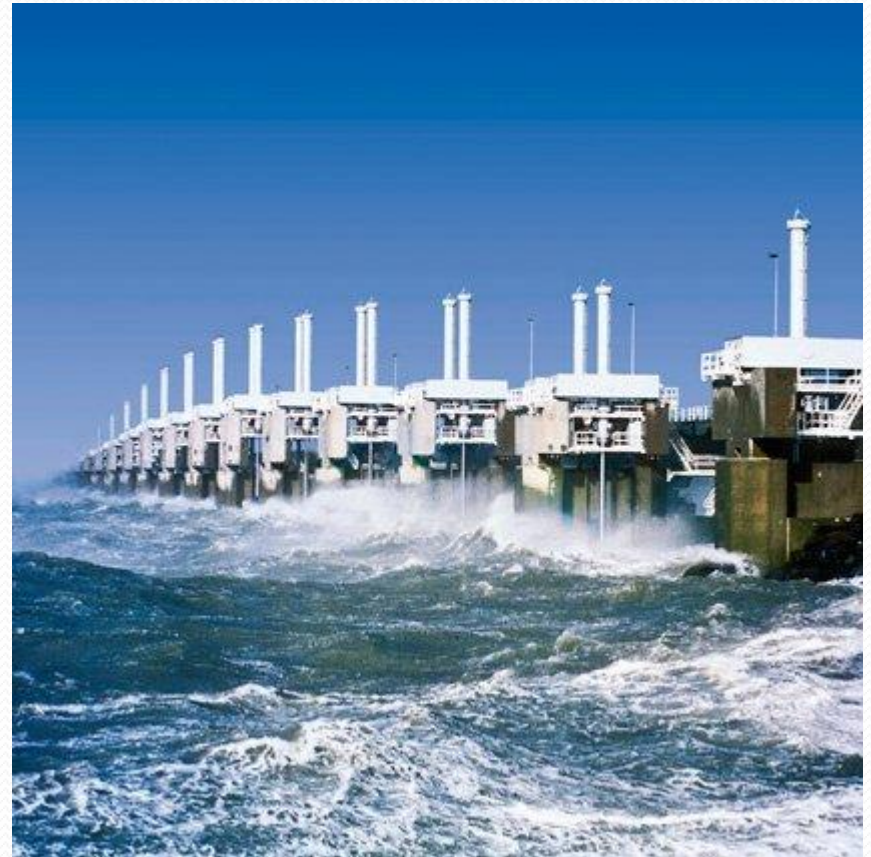


Implementation of Dynamic Preservation Policy

Implementation was based on:

- (1) a quantitative concept of the actual state of the system;
- (2) procedures for objective benchmarking;
- (3) procedures for preferred interventions;
- (4) procedures for evaluation.

[view of storm surge](#)



The '*Decision recipe*' of the Dynamic Preservation Policy

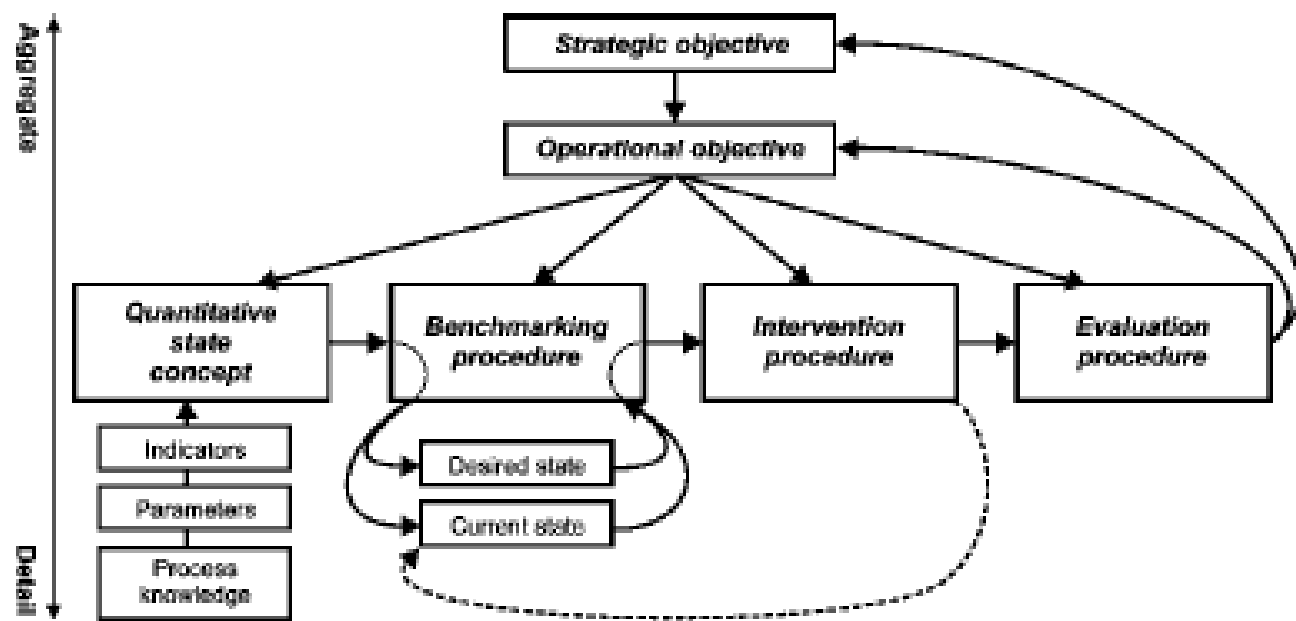


Figure 2. A basic frame of reference for policy development (Source: VAN KONINGSVELD, 2003).

Building with nature's toolbox (Ecoshape, 2014)

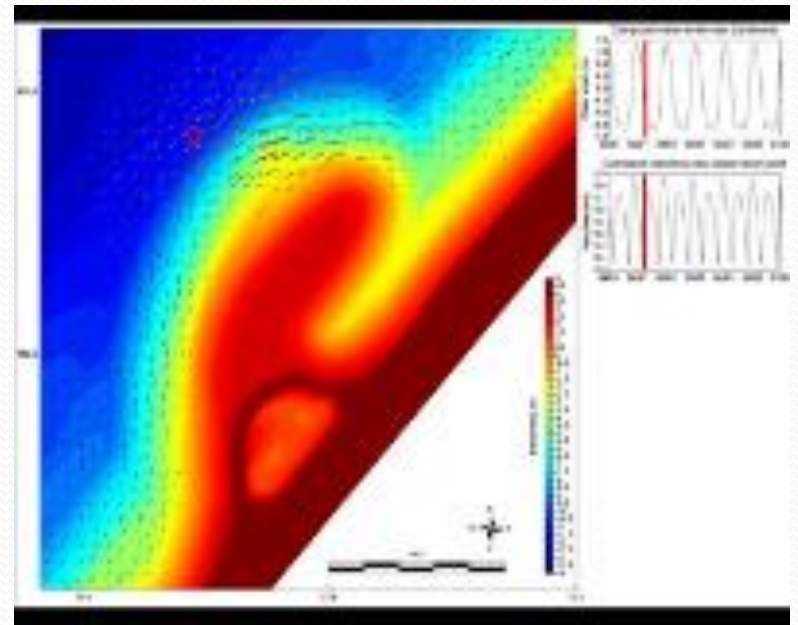
- Based on the idea of making full use of 'natural processes'
 - E.g. beach nourishment was the principal approach (Dean, 2002; Vriend et al, 2014)
 - Dredged sand from North Sea
 - Amount needed increased from 6 million m³ 1990 – 12 million m³ per year since 2001 - 2014
 - Successfully held the 1990 line and reduced vulnerability
 - Increased sustainability ((van Koningsveld & Mulder, 2004)
 - However it creates a permanent state of ecosystem disturbance about every 5 years (Baptist, 2008) and over steepens the profile which leads to the need for additional nourishment (Strive, 2001).
 - Hence the policy moved to concentrated nourishment which is redistributed by natural processes.
 - This limits ecosystem disturbance, lowers unit costs and creates areas for recreation / ecology



Recent example: Delfland sand engine

- Full scale experiment Started 2011
- Designed for a 20 year period
- Designed for seals, flat fish due to the shallow lagoon and spit
- Onshore sand blown predicted to create pioneer dunes and associated habitat
- 2013 monitoring shows the natural processes are working in expected fashion (Aolian & coastal)
- Also, good for recreation (Esp. kite surfing) (Vriend et al, 2014)
- Delft 3D model of hydro dynamics and ecology.

How good is modelling?



2013 after 18 mths



Predicted
sediment
transfer



Delfland sand engine New nourishment

Building with Nature	Traditional nourishment
A surplus of sand (in case of the pilot project Sand Motor, order 20 million m³; 10,000 m³ per linear m of coastline) is put into the natural system and is expected to be re-distributed alongshore and into the dunes through the continuous natural action of waves, tides and wind. In this way mega-nourishments gradually induce dune formation along a larger stretch of coastline over a period of one or more decades, thus contributing to coastal safety against flooding over a longer period of time and giving less disturbance to the coastal ecosystem while creating opportunities for nature and recreation	A traditional design of a sand nourishment in the Netherlands, has the primary objective of shoreline maintenance using a medium volume of sand (2-5 million m³; typically 200- 400 m³/m). The lifespan of the nourishment is in the order of 5 years. This means that every 5 years the nourishment has to be repeated, resulting in a frequent disturbance of the ecosystem. (Aarninkhof, 2014)

Student led seminars

Seminar 1

Developing a plan

- In pairs construct a soft and hard engineering plan for a coastal location of your choice.
- Argue your case on a flipchart
- Gather supportive evidence and examples to highlight the reasons for your decisions



Seminar 2

Coastal management should be based on the use of a calculator?

- Watch this National Geographic episode on the history of Dutch coastal management structures.
- What lessons does it provide for 'your' coastal management case in the UK? (Seminar 1)?
- Construct a PowerPoint that presents your case based on what you have learnt.
- Dutch coastal management (50mins)

